What is claimed is:

1. A method of beam forming comprising the steps of:

in an appliqué intelligent antenna system, monitoring broadcast channels of a mobile wireless base station;

monitoring a frequency burst broadcast by the base station and synchronizing the appliqué system in frequency;

monitoring a synchronization burst in the broadcasting channel and synchronizing the appliqué system with the mobile wireless base station in time.

2. A method as claimed in claim 1 further comprising the step of the base station receiving an access response for a remote terminal and in response thereto, including any processing delay of the appliqué system as part of a round-trip delay for the remote terminal;

3. A method as claimed in claim 2 wherein the step of the base station including any processing delay includes determining a timing advance value corresponding to a round-trip delay plus an appliqué system processing delay.

4. A method as claimed in claim 2 further comprising the step of the base station transmitting the timing advance value to instruct the remote terminal to transmit earlier than the normal system time thereby compensating for both the round-trip delay and the appliqué system processing delay.

5. A method as claimed in claim 1 wherein the step of monitoring a synchronization burst includes the step of detecting locally the system information carried by synchronization burst.

6. A method as claimed in claim 2 wherein the step of detecting includes regularly checking a slot 0 of broadcast control channel (BCCH) carrier.

7. A method as claimed in claim 6 wherein the step of detecting includes the steps of doing fast frequency synchronization and searching for a frame boundary by using both a frequency burst (FB) and a synchronization burst (SB).

8. A method as claimed in claim 7 including a steps of decoding the synchronization burst (SB) to determine three parts of the reduced TDMA frame number (RFN) T1, T2, T3' and to derive an exact frame number.

9. A method as claimed in claim 8 including a step of calculating the frequency-hopping pattern.

10. A method as claimed in claim 9 including a step of decoding BCCH information to obtain timing advance for downlink beam forming power control.

11. A method as claimed in claim 10 including a step of decoding a paging channel (PCH).

12. A method as claimed in claim 10 including a step of decoding an access grant channel (AGCH).

13. A method as claimed in claim 12 including a step of determining mobile terminal positioning using information from the access grant channel.

14. A method as claimed in claim 10 including a step of decoding a request access channel (RACH) from a remote terminal.

15. A method as claimed in claim 14 including a step of decoding an access grant channel (AGCH).

16. A method as claimed in claim 15 including a step of determining mobile terminal positioning using information from access request and access grant channels.

17. A method as claimed in claim 16 including wherein the step of determining the mobile terminal position includes the step of determining angle of arrival of a response received from the remote terminal.

18. A method as claimed in claim 17 wherein the step of determining the angle of arrival includes the step of determining a covariance matrix XX, where X is given by:

$$\begin{bmatrix} R1(62) & R2(62) & R3(62) & R4(62) \\ R1(63) & R2(63) & R3(63) & R4(63) \\ R1(64) & R2(64) & R3(64) & R4(64) \\ & \vdots & & \\ R1(87) & R2(87) & R3(87) & R4(87) \end{bmatrix}$$

And $XX = X^* \bullet X$

19. A method as claimed in claim 18 wherein the step of determining the angle of arrival includes the step of forming a Hermitian Toeplitz matrix by using XX with the following procedures

$Z_0 = [XX(1,1) + XX(2,2) + XX(3,3) + XX(4,4)] / 4;$

$Z_1 = [XX(1,2) + XX(2,3) + XX(3,4)] / 3;$

$Z_2 = [XX(1,3) + XX(2,4)] / 2;$

$Z_3 = XX(1,4);$

$$ZZ = \begin{pmatrix} Z_0 & Z_1 & Z_2 & Z_3 \\ conj(Z_1) & Z_0 & Z_1 & Z_2 \\ conj(Z_2) & conj(Z_1) & Z_0 & Z_1 \\ conj(Z_3) & conj(Z_{2)} & conj(Z_1) & Z_0 \end{pmatrix}.$$

20. A method as claimed in claim 19 wherein the step of determining the angle of arrival includes a step of performing singular value decomposition of ZZ to have ZZ $= \mathrm{V}\ \Lambda\ \mathrm{conj(V)}^{\mathrm{T}}$, where V is an orthogonal unit matrix formed by eigenvectors of ZZ and Λ is a diagonal matrix formed by four eigenvalues.

21. A method as claimed in claim 20 wherein the step of determining the angle of arrival includes a step of selecting a largest eigenvalue from among the four eigenvalues and forming a noise vector matrix by those eigenvectors not corresponding to the largest eigenvector.

22. A method as claimed in claim 21 wherein the step of determining the angle of arrival includes the step of forming a polynomial and finding a root by referring to a look-up table.

23. A method as claimed in claim 22 wherein the step of determining the angle of arrival includes the step of converting the root into an angle of arrival in degrees.

24. A method as claimed in claim 23 including the step of downlink beam forming the intelligent antenna array for the mobile terminal in dependence upon the angle of arrival of the strongest multipath signal.

25. A method as claimed in claim 21 wherein the step of determining the angle of arrival includes the step of forming a polynomial and finding a root by decomposing a companion matrix.

26. A method as claimed in claim 25 wherein the step of determining the angle of arrival includes the step of converting the root into an angle of arrival in degrees.

27. A method as claimed in claim 26 including the step of downlink beam forming the intelligent antenna array for the mobile terminal in dependence upon the angle of arrival of the strongest multipath signal.

28. A method as claimed in claim 27 wherein the step of downlink beam forming includes the steps framing data to form four slot data vectors y1, y2, y3, y4 where:

y_1= R1(1),R1(2),R1(3),R1(4),...,R1(61),R1(62),...,R1(87),R1(88),...,R1(145),R1(146),R1(147),R1(148), R1(149),...,R1(156)

y_2=R2(1),R2(2),R2(3),R2(4),...,R2(61),R2(62),...,R2(87),R2(88),...,R2(145),R2(146),R2(147),R2(148), R2(149),...,R2(156)

y_3= R3(1),R3(2),R3(3),R3(4),...,R3(61),R3(62),...,R3(87),R3(88),...,R3(145),R3(146),R3(147),R3(148), R3(149),...,R3(156)

y_4= R4(1),R4(2),R4(3),R4(4),...,R4(61),R4(62),...,R4(87),R4(88),...,R4(145),R4(146),R4(147),R4(148), R4(149),...,R4(156);

extracting data vectors corresponding a training sequence, that is those having a data position from index 62 to index 87;

estimating multipath channels with the following formulae

$$S=\begin{bmatrix} s(K_1) & s(K_1+1) & \dots & s(K_1+6) \\ s(K_1+1) & s(K_1+2) & \dots & s(K_1+7) \\ \dots & \dots & \dots & \dots \\ s(K_2-6) & s(K_2-5) & \dots & s(K_2) \end{bmatrix}$$

where $s(K_1)$, $s(K_1+1)$,..., $s(K_2)$ are part of the known training sequence transmitted by a mobile terminal that is also known by the base station; and

then obtaining each multipath channel impulse response by solving the following linear equations:

$$S\begin{bmatrix} ch1(6) \\ ch1(5) \\ \vdots \\ ch1(0) \end{bmatrix} + \begin{bmatrix} N(K_1) \\ N(K_1+1) \\ \vdots \\ N(K_2-6) \end{bmatrix} = \begin{bmatrix} y1(K_1+6) \\ y1(K_1+7) \\ \vdots \\ y1(K_2) \end{bmatrix}$$

$$S\begin{bmatrix} ch2(6) \\ ch2(5) \\ \vdots \\ ch2(0) \end{bmatrix} + \begin{bmatrix} N(K_1) \\ N(K_1+1) \\ \vdots \\ N(K_2-6) \end{bmatrix} = \begin{bmatrix} y2(K_1+6) \\ y2(K_1+7) \\ \vdots \\ y2(K_2) \end{bmatrix}$$

$$S\begin{bmatrix} ch3(6) \\ ch3(5) \\ \vdots \\ ch3(0) \end{bmatrix} + \begin{bmatrix} N(K_1) \\ N(K_1+1) \\ \vdots \\ N(K_2-6) \end{bmatrix} = \begin{bmatrix} y3(K_1+6) \\ y3(K_1+7) \\ \vdots \\ y3(K_2) \end{bmatrix}$$

$$S\begin{bmatrix} ch4(6) \\ ch4(5) \\ \vdots \\ ch4(0) \end{bmatrix} + \begin{bmatrix} N(K_1) \\ N(K_1+1) \\ \vdots \\ N(K_2-6) \end{bmatrix} = \begin{bmatrix} y4(K_1+6) \\ y4(K_1+7) \\ \vdots \\ y4(K_2) \end{bmatrix}$$

having explicit least mean square error solutions:

$$\begin{bmatrix} ch1(6) \\ ch1(5) \\ \vdots \\ ch1(0) \end{bmatrix} = (conj(S)^T S)^{-1} \begin{bmatrix} y1(K_1+6) \\ y1(K_1+7) \\ \vdots \\ y1(K_2) \end{bmatrix}, \quad \begin{bmatrix} ch2(6) \\ ch2(5) \\ \vdots \\ ch2(0) \end{bmatrix} = (conj(S)^T S)^{-1} \begin{bmatrix} y2(K_1+6) \\ y2(K_1+7) \\ \vdots \\ y2(K_2) \end{bmatrix},$$

$$\begin{bmatrix} ch3(6) \\ ch3(5) \\ \vdots \\ ch3(0) \end{bmatrix} = (conj(S)^T S)^{-1} \begin{bmatrix} y3(K_1+6) \\ y3(K_1+7) \\ \vdots \\ y3(K_2) \end{bmatrix}, \quad \begin{bmatrix} ch4(6) \\ ch4(5) \\ \vdots \\ ch4(0) \end{bmatrix} = (conj(S)^T S)^{-1} \begin{bmatrix} y4(K_1+6) \\ y4(K_1+7) \\ \vdots \\ y4(K_2) \end{bmatrix}.$$

29. A method as claimed in claim 28 wherein the matrix S is formed by the known training sequence and an inverse matrix is pre-determined and stored in memory.

30. A method as claimed in claim 28 wherein the step of downlink beam forming includes a step of forming a data matrix H

$$H=\begin{bmatrix} y_1(k) & y_1(k+1) & \cdots & y_1(k+25) \\ y_2(k) & y_2(k+1) & \cdots & y_2(k+25) \\ y_3(k) & y_3(k+1) & \cdots & y_3(k+25) \\ y_4(k) & y_4(k+1) & \cdots & y_4(k+25) \end{bmatrix} - \begin{pmatrix} ch_1(0) & ch_1(1) & \cdots & ch_1(6) \\ ch_2(0) & ch_2(1) & \cdots & ch_2(6) \\ ch_3(0) & ch_3(1) & \cdots & ch_3(6) \\ ch_4(0) & ch_4(1) & \cdots & ch_4(6) \end{pmatrix} \begin{pmatrix} s(k) & s(k+1) & \cdots & s(k+25) \\ s(k-1) & s(k) & \cdots & s(k+24) \\ \cdots & \cdots & \cdots & \cdots \\ s(k-6) & s(k-5) & \cdots & s(k+19) \end{pmatrix}$$

with k = 62.

31. A method as claimed in claim 30 wherein the step of downlink beam forming includes a step of choosing an optimal beam former by solving an optimization problem:

$$\min\{w^T ININ^T w = w^T HH^T w, s.t. \|w\|^2 = 1\}$$

whose solution is an eigenvalue problem of a 4x4 semi-definite positive Hermitian matrix, that has an explicit solution.

32. A method as claimed in claim 31 including a step of solving the optimization problem by doing eigenvalue decomposition for the 4x4 Hermitian matrix HH^T.

33. A method as claimed in claim 1 further comprising the step of uplink beam forming.

34. A method as claimed in claim 33 including the steps of:

estimating angle of arrival (AOA) estimation by determining a covariance matrix XX, where X is given by:

$$\begin{bmatrix} R1(62) & R2(62) & R3(62) & R4(62) \\ R1(63) & R2(63) & R3(63) & R4(63) \\ R1(64) & R2(64) & R3(64) & R4(64) \\ & \vdots & & \\ R1(87) & R2(87) & R3(87) & R4(87) \end{bmatrix}$$

And XX = X* • X

35. A method as claimed in claim 34 wherein the step of determining the angle of arrival includes the step of determining a covariance matrix XX, where X is given by:

$$\begin{bmatrix} R1(62) & R2(62) & R3(62) & R4(62) \\ R1(63) & R2(63) & R3(63) & R4(63) \\ R1(64) & R2(64) & R3(64) & R4(64) \\ & \vdots & & \\ R1(87) & R2(87) & R3(87) & R4(87) \end{bmatrix}$$

And $XX = X^* \bullet X$

36. A method as claimed in claim 35 wherein the step of determining the angle of arrival includes the step of forming a Hermitian Toeplitz matrix by using XX with the following procedures

$$Z_0 = [XX(1,1) + XX(2,2) + XX(3,3) + XX(4,4)] / 4;$$
$$Z_1 = [XX(1,2) + XX(2,3) + XX(3,4)] / 3;$$
$$Z_2 = [XX(1,3) + XX(2,4)] / 2;$$
$$Z_3 = XX(1,4);$$

$$ZZ = \begin{pmatrix} Z_0 & Z_1 & Z_2 & Z_3 \\ conj(Z_1) & Z_0 & Z_1 & Z_2 \\ conj(Z_2) & conj(Z_1) & Z_0 & Z_1 \\ conj(Z_3) & conj(Z_2) & conj(Z_1) & Z_0 \end{pmatrix}$$

37. A method as claimed in claim 36 wherein the step of determining the angle of arrival includes a step of performing singular value decomposition of ZZ to have $ZZ = V \Lambda \, conj(V)^T$, where V is an orthogonal unit matrix formed by eigenvectors of ZZ and Λ is a diagonal matrix formed by four eigenvalues.

38. A method as claimed in claim 27 wherein the step of determining the angle of arrival includes a step of selecting a largest eigenvalue from among the four eigenvalues and forming a noise vector matrix by those eigenvectors not corresponding to the largest eigenvector.

39. A method as claimed in claim 38 wherein the step of determining the angle of arrival includes the step of forming a polynomial and finding a root by referring to a look-up table.

40. A method as claimed in claim 39 wherein the step of determining the angle of arrival includes the step of converting the root into an angle of arrival in degrees.

41. A method as claimed in claim 38 wherein the step of determining the angle of arrival includes the step of forming a polynomial and finding a root by decomposing a companion matrix.

42.. A method as claimed in claim 41 wherein the step of determining the angle of arrival includes the step of converting the root into an angle of arrival in degrees.

43. A method a claimed in claim 42 including a step of calculating four beam weights to form a downlink beam comprising a 30 degree beam pointing to the direction of the estimated AOA

44. A method as claimed in claim 1 wherein a separation between each antenna of the intelligent antenna array is $(5^{½} - 1)/2$ times the wavelength.